RADIUM

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A MONTHLY JOURNAL DEVOTED TO THE CHEMISTRY PHYSICS AND THERAPEUTICS OF RADIUM AND RADIO-ACTIVE SUBSTANCES

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Edited and Published by Charles H. Viol, Ph. D., and William H. Cameron, M. D. with the assistance of collaborators working in the fields of Radiochemistry, Radioactivity and Radiumtherapy.

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VOL. IX MAY, 1917 No. 2

A REPORT OF THE WORK OF THE MANCHESTER AND DISTRICT RADIUM INSTITUTE*

FROM JANUARY 1st, 1916, TO DECEMBER 31st, 1916.

By Arthur Burrows, M. D., *Radiologist.*
Manchester, England.

This report deals with the first thousand cases which have presented themselves at the Manchester and District Radium Institute with a view to Radium treatment. It represents practically two years' work.

Although in the case of malignant diseases no patients are treated by radiation unless the Surgeon has previously declared them to be inoperable, a certain number of those who came for consultation were suffering from the disease in far too advanced a stage to hope for any benefit from the application of Radium. In addition, some who were deemed suitable for the therapeutic employment of Radium did not keep their appointments when their turn for treatment arrived.

Included in the report, in addition to a general table of all the cases which have been treated, is also a list of all the malignant cases, excepting Rodent Ulcers, which were well at the end of 1916. This list states the time during which they have been quite free from symptoms or signs of disease.

As the Institution has only been open for two years, no patient can have experienced a period of freedom for more than twenty-four months. In addition to this no case of Carcinoma of the Breast was reported as being apparently well at the end of last year. Thus, in this particular instance, twelve months is the maximum period during which any patient previously suffering from the disease can have been free from symptoms.

*The first Report from the Manchester and District Radium Institute was reprinted in RADIUM, Vol. VII, No. 1, April, 1916.

In order to make the records as instructive and valuable as possible, practically all the patients have been written to regularly to ensure their attendance at the Institute. As is inevitable, however, even in these circumstances, a number have not returned for re-examination, and it has been necessary to put them under the heading of "Abandoned treatment." That these cases are not all failures is evident from the fact that now and again a case will reappear, either quite well or because there is a return of a symptom which had disappeared. This is particularly noticeable in respect to patients suffering from small Rodent Ulcers, as a single treatment often removes all manifestations of the growth, and the patient's thoughts are no longer fixed upon their trouble.

During the year the Physicist, Mr. Lupton, has been employed for part of his time on munition work at the University. This, coupled with the fact that the present is a difficult time to construct a Research Laboratory, has limited the energies of the Institute to the purely clinical side of its work; but it is hoped that as soon as circumstances permit, an increase in the scope of its activities will be possible.

Mr. Lupton reports that 777 ordinary emanation tubes, 238 emanation tubes for needles, and 316 flat emanation applicators were made during the past year in the Physical laboratory. This shows an increase of 251 over the year 1915.

The decrease in the number of patients registered is accounted for by the long Waiting List which was in existence when the Institute was opened. That the work has really increased is shown by the larger number of applicators and tubes made, and by an increase of 140 in the patients' attendances.

During the past twelve months, Drs. Powell White and Harris, of the Cancer Research Laboratory of the University, have prepared and reported on twenty sections of the various growths and morbid tissues submitted to them for microscopic examination. A large number of other growths have been examined at the Clinical Laboratories of the various hospitals participating in the Scheme.

Sixteen military patients have been treated for various diseases during the past year.

TABLE I.—In this table a list is given of all the cases of malignant disease, with the exception of Rodent Ulcers, which were well on December 31st, 1916. It states also the period during which patients were free from symptoms or signs. The following notes are necessary in explanation:—

(*a*) CARCINOMA OF THE BLADDER.—One patient was reported last year as being free from symptoms, but a return of haematuria nine months later necessitated a second application of Radium. He has now been well for four months.

(*b*) CARCINOMA OF THE BREAST.—No cases were reported as being well last year, so that in no instance has a patient been apparently free of the disease for more than twelve months.

(*c*) CARCINOMA OF THE CERVIX OF THE UTERUS.—Two of the cases reported well last year have had a recurrence of disease.

(*d*) CARCINOMA OF THE LARYNX.—The case of Carcinoma of the Larynx reported well last year has recurred.

(*e*) CARCINOMA OF THE TONSIL.—One case was reported last year as being apparently cured. It appears to have been an error of diagnosis. It was probably a case of Lymphosarcoma, and as such has since manifested itself.

TABLE I.

Disease.	Sex	Age	Period of apparent freedom from disease
CARCINOMA:			
Carcinoma bladder	M.	55	4 months
" "	M.	63	8 "
" "	M.	48	4 "
Carcinoma breast	F.	43	6 "
" "	F.	47	2 "
" "	F.	51	3 "
" "	F.	50	4 "
" "	F.	81	12 "
" "	F.	50	6 "
" "	F.	42	4 "
" "	F.	72	1 "
Carcinoma cervix uteri	F.	60	1 "
" " "	F.	59	6 "
" " "	F.	62	19 "
" " "	F.	47	14 "
" " "	F.	58	6 "
Carcinoma colon	F.	39	18 "
Carcinoma ear	F.	66	6 "
Carcinoma lip	F.	60	10 "
Carcinoma mouth	M.	63	4 "
" "	M.	50	7 "
Carcinoma ovary	F.	51	18 "
Carcinoma parotid	M.	49	4 "
Carcinoma skin	M.	51	3 "
" "	M.	58	9 "
" "	M.	78	13 "
" "	M.	60	4 "
" "	M.	73	3 "
" "	M.	43	6 "
" "	M.	71	13 "
" "	M.	47	16 "
" "	M.	64	7 "
" "	F.	65	5 "
" "	M.	38	14 "
" "	M.	78	3 "
" "	M.	60	5 "
Carcinoma tongue	M.	62	5 "
" "	F.	60	10 "
" "	F.	65	14 "
Carcinoma tonsil	M.	54	6 "
Carcinoma thyroid	F.	47	21 "
SARCOMA			
Sarcoma naso-pharynx	M.	10	19 months
" "	M.	17	15 "
" muscle"	M.	52	3 "
" tibia	M.	18	8 "
ENDOTHELIOMA			
Endothelioma parotid	M.	46	7 months

(*f*) CARCINOMA OF THE SKIN.—All these cases have remained quite well.

(*g*) SARCOMA MUSCLE.—One case reported last year as being well has recurred.

(*h*) Sarcoma Naso-pharynx.—Owing to lack of information it was impossible to publish information on one of these cases in last year's report. Recently this case has been seen again, and is apparently well.

The notes above show that five cases indicated in the table last year as being well at the end of that time have, after varying periods of immunity, relapsed, whilst one which recurred but was re-treated is free from symptoms and signs again. Thus, of the seventeen cases reported as being apparently free of the disease at the end of 1915, twelve still remain well. Of course, all the cases of malignant disease reported in the following list were regarded as inoperable by the Surgeon.

A Series of Cases Illustrating Interesting Points in Relationship to Radium Treatment.

Carcinoma of the Bladder. — These cases have been treated chiefly through supra-pubic openings, which surgeons had made for the purposes of their own investigations. In the more localised cases it has been possible sometimes to bury a tube in the growth at the time of operation, otherwise a general irradiation has been given by passing a tube down through the supra-pubic opening. Radium has also been applied as a prophylactic by burying a tube or tubes at the site of the excision of a growth. Multiple Papillomata of the Bladder have been treated in the same way.

Example I.—Male, aged 55—This patient suffered on and off for five years with haematuria, pain, and difficulty on micturition. Two years ago a growth was removed surgically from the bladder. He was then well for the subsequent eight months, when some haemorrhage returned. In February, 1914, a suprapubic cystotomy was performed again, and a growth was found to occupy practically the whole of the inner wall of the bladder, and was quite inoperable. Thirty millicuries of Radium emanation were passed down the supra-pubic opening into the bladder in a screen of 1 m. m. of silver, and left in position for fifteen hours. The patient remained well for eight months when slight haematuria appeared again. Cystoscopic examination showed one small node of growth. Treatment was then given to the bladder per urethram for twelve hours, and the patient has been quite well ever since.

Example 2.—Male, aged 48.—This patient had a three years' history of pain and haematuria. In January, 1914, a small papilloma was removed from the region of the right uretic orifice. In February, 1916, an indurating growth was in part removed surgically. A tube was buried at the site of the removal. A few days later a general irradiation of the bladder was given for twenty-four hours. He has been in perfect health every since.

Carcinoma of the Breast.—In this instance the best results follow the implantation of an adequate number of emanation tubes in the growth and along the course of the lymphatic vessels. In some cases as many as twelve tubes have been buried at one time. If the tumor be very firmly fixed to the chest wall the results are not so good, and treatment by implantation must be employed with extreme caution or the breaking down of the growth may produce an intractable ulcer. Often it is better not to bury at all under these circumstances, but simply to apply plates externally. It is always necessary to convince oneself that the situation and size of the growth give adequate opportunities for local repair. If the growth of the breast be too large, it is best to remove it locally and to apply radium at the site of removal, and along the

lymphatic tract. Radium is also most useful in assisting surgeons to operate in borderline cases, or for the treatment of inoperable glands of the neck. Small scattered glands of the neck may be treated by the application of plates or larger masses by the method of burying. In the latter instance the results are often most gratifying. Small secondary skin nodules disappear when treated by superficial plates, but their widespread nature inclines one to think that it is likely that X-ray treatment would be the best method of dealing with them in the future.

It is by no means always necessary to produce a severe local reaction in order to remove a malignant growth by Radium. It is often done without the patient's knowledge that anything is happening at all; and increase of knowledge will no doubt practically eliminate the occurrence of a reaction which is a source of discomfort to the patient.

Example 1.—Female, aged 72.—This patient had a two years' history of a swelling of the right breast with the formation of a lump in the right axilla. She had only slight symptoms of discomfort. Her surgeon deemed her growth to be inoperable.

In the upper and outer quadrant of the right breast was a hard mass, the size of a hen's egg. It was adherent to the skin, but could be moved somewhat on the chest wall. In the right axilla was a mass of six or more hard glands adherent to one another. Slight movement of them in the deep tissues was possible.

Five Radium emanation tubes (each of 20 mc. strength, and contained in screens of platinum 3/10 mm. thick) were buried in the breast (three) and axilla (two) for twenty-four hours. The growth diminished much and treatment was repeated two months later with four tubes. Three months later some indefinite thickening remained in the right breast, one gland could be felt in the right axilla, and one small supraclavicular gland had appeared. Treatment was continued by the external application of Radium plates, screened by 1.5 mm. of lead, for twenty-four hours. This was repeated six weeks later, and seven months after the first application of Radium all signs of the growth had disappeared.

The above is an example which shows how much perseverance is sometimes necessary. Other cases have cleared up more quickly, and it has not been necessary to apply plates.

Example 2.—Female, aged 50.—In 1913 radical amputation of this patient's right breast was performed for Carcinoma. Twelve months later a nodule appeared at the inner end of the scar. The nodule gradually grew, and eventually broke down and ulcerated. When she presented herself with a view to Radium treatment, she had at the sternal end of the breast scar an elliptical ulcer 3 x 2 cm. It was surrounded by a zone of infiltration measuring 1cm. across, and its edges were thickened, hard and undermined. The whole ulcer was intimately united with, and fixed to, the chest wall. In the neck above the inner end of the clavicle was a hard rounded gland the size of a hazel nut. It was not firmly fixed. No enlarged glands could be felt elsewhere. Looking to the nature and situation of the ulcer it was decided that treatment by external plates was the only method available. The patient received nine applications of plates of a strength of 2.5 mg. of Radium to the square centimetre, screened by 5mm. of platinum, for twenty-five hours, both to gland and ulcer, an interval of six weeks elapsing between each application. At the end of that period both the gland and the ulcer had disappeared, leaving no sign of the growth.

The above example shows that occasionally a good result may be obtained in an apparently unpromising case by the use of plates alone.

CARCINOMA OF THE CERVIX OF THE UTERUS.—Cases of Carcinoma of the Cervix of the Uterus in which the vaginal wall is extensively involved are in most cases best left alone. Short of this, however, a large proportion of cases can be given six to twelve months' immunity from symptoms, together with remarkable improvement in general health. The tendency is to give increasingly larger doses, employing six or seven or more tubes or needles. Under these conditions it is likely to become the rule rather than the exception to remove the cervical growth altogether.

Example 1.—Female, aged 42.—This patient had a two years' history of loss of weight and a vaginal discharge. For three months the discharge had been bloody, and she had suffered from pain in the lower abdomen and back. She had four treatments of twenty-four hours each with tubes, the wall of which was 1 mm. of silver or 3/10 mm. platinum thick. The dose used was from 36 to 80 mc. There was slight improvement on each occasion. Subsequently 140 mc. of emanation were introduced into the cervix in six tubes at one time for twenty-four hours. Five weeks later all ulceration, pain and discharge had gone, and only a small area of induration remained in the left side. This example shows well the value of large doses.

Example 2.—Female, aged 59.—In this case the patient had been suffering from abdominal pain and a bloody vaginal discharge for five months. She had a large friable growth of the posterior lip of the cervix extending also well up the cervical canal. The uterus was tethered to the left side by induration running into the left broad ligament. Two small treatments produced slight improvement, a third much larger one cleared away all signs of the growth, and the patient has remained quite well since.

CARCINOMA OF THE COLON.—It is not usual in these cases to get any very marked improvement from the application of Radium plates to the abdomen over the site of a growth, nor is it common on laparotomy to find one in which it is possible to implant Radium emanation tubes. Occasionally, however, it has been found practicable to do so.

Example 1.—Female, aged 39.—This patient suffered for nine months from abdominal pain and constipation. She was admitted to the Manchester Royal Infirmary with chronic intestinal obstruction, which was relieved by enemata. When this had been done a large hard fixed tumor could be felt on palpation in the left iliac fossa. Laparotomy was subsequently performed, and a mass, the size of a tangerine orange, was found growing from the outer wall of the descending colon at the region where it joins the sigmoid flexure. The mass was adherent to the abdominal wall. Two tubes were buried in the growth. Within a short period all the pain had gone, the constipation could be controlled by medicine and the palpable tumour was about half its original size. After five months the treatment was repeated, and a few months later the patient returned with abdominal pain and constipation. On opening the abdomen it was found that the site of the growth was occupied only by a band of fibrous thickening, and the Surgeon was of the opinion that the symptoms were entirely due to the constriction. Some Radium was buried as a precaution, with instructions that the patient was to return later for lateral anastomosis to be performed.

Example 2.—Female, aged 45.—This patient had been suffering for

over twelve months from persistent vomiting, constipation, and pain. Laparotomy was performed in January, 1915, but the growth was found to be quite inoperable, so nothing further was attempted. In February, 1916, a large mass could be felt in the right hypochondrium, and it was decided again to explore the abdomen with a view to Radium treatment. On this occasion a large Carcinoma of the hepatic flexure of the colon was found. It was adherent to the abdominal wall, but the stomach did not appear to be involved. No growth was found in the liver, but there were a few enlarged glands in the mesentery. Three tubes of Radium, each of a strength of 20 mc. and screened by 3/10 mm. of platinum, were buried in the growth and glands for twenty-four hours. Up till the end of June the patient gained in weight, ceased vomiting, and suffered much less pain. It was decided to re-open the abdomen and implant more Radium. At the operation the malignant mass was found to be much smaller and more movable. Three tubes were inserted in the growth, and one in the mesenteric glands, all for twenty-four hours. In December, 1916, only slight thickening could be felt in the region of the growth, and the patient was completely free of symptoms.

CARCINOMA OF THE MOUTH AND TONGUE.—The treatment of Neoplasms of the Mouth and Tongue by Radium does not appear to be making much progress at present. Those cases in which a satisfactory result has been obtained have either been large ulcers right at the back of the tongue, or small growths which were inoperable merely as a result of their positions.

Example 1.—Female, aged 60.—This patient had a history of soreness of the throat for a year, and for some months her voice had been hoarse. At the back of the tongue, not directly visible from the mouth, was an ulcer occupying the left two-thirds of the posterior part of the tongue and measuring about 2 cm. across. It was deeply indurated beneath, and the thickening extended across the whole breadth of the tongue. Under the left angle of the jaw were two large hard glands, each the size of a marble. A Radium emanation tube of the strength of 18 mc., contained in a cylinder of silver the wall of which was 1 cm. thick, was inserted into the floor of the ulcer. Six weeks later the ulcer had healed over completely, but some induration remained. Twice subsequently tubes were buried in the ulcer and the glands. For the last ten months the patient has been quite free from any sign of the disease.

Example 2.—Male, aged 63.—The patient had a history of pain in the right side of the throat for three years. When he came for examination there was an indurated growth covering the right anterior pillar of the fauces, spreading downwards and involving a small portion of the tongue. No glands were palpable. Four emanation needles of Stevenson & Joly's type, each of the strength of 4 mc. and screened by 3/10 mm. of steel, were inserted into the growth for twelve hours. Two months later the growth had disappeared except for two small nodules, one at the top and one at the bottom of the site of the original lesion. Three more needles were buried again for twelve hours, and six weeks later no sign of the growth remained. The patient was still quite well at the end of December, 1916.

CARCINOMA OF THE RECTUM.—If the growth be not too near the anal margin, it is worth while giving the patient two or three applications of Radium; but although the immediate relief may be very great, as a rule the patient eventually relapses and the treatment is of no further

avail. One case which had been treated three times was seen subsequently by the Surgeon, who thought the growth had become operable, but unfortunately the patient did not submit himself to operation. An attempt has been made to bury tubes in one or two cases, but the results have not been very satisfactory.

Example 1.—Female, aged 52.—This patient had a three years' history of tenesmus and pain in the lower part of the back. She also suffered from rectal haemorrhage. About 8 cm. up the rectum could be felt the lower end of a hard ulcerated annular growth, which appeared to be almost completely fixed. Anteriorly deep induration reached forward to the vagina, to which the mass was adherent. The induration also extended considerably on the left-hand side. She was treated by inserting in the lumen of the growth a tube of 25 mg. of Radium in a screen of 2 mm. of lead. It was applied for twenty-four hours in all. Six weeks later the growth was a trifle smaller, and the patient suffered no longer from pain or bleeding. She slept well, ate well, and was able to resume work. She felt better than she had done for two years. Similar treatment was given subsequently, and the patient put on ten pounds in weight, keeping in good health for eight months, then her symptoms gradually returned, and her general health became worse in spite of further treatment.

Carcinoma of the Skin.—Carcinoma of the skin in its earlier stages can be treated in a manner very similar to rodent ulcers. The disease when it comes to the Radium Institute, however, is usually much further advanced. Commonly there is a large deep ulcer with much induration beneath and a heaped-up and hard surrounding edge. There are frequently secondary glands. The growth is, of course, in some instances too extensive to hope for much benefit from Radium treatment. Very frequently, however, brilliant results are obtained. It is necessary in the more advanced cases to bury tubes of Radium emanation in the edges of the ulcer, and often in its base. Stevenson & Joly's needles are also of great value in the treatment of this condition. They can be inserted into the ulcer for periods of six to twelve hours without the use of a general anaesthetic.

Example 1.—Male, aged 60.—This patient had been suffering for three months with a swelling behind his left ear. For about six weeks it had become ulcerated, and had grown steadily in size. The ulcer, when the patient came to be seen, was 2.5 cm. in diameter, and was considerably raised above the surrounding skin. There was much induration around and beneath it, and its base was firmly adherent to bone. A doubtful gland was present in the left side of the neck. Treatment by Radium plates had little effect, and subsequently four emanation tubes, the four together containing 40 mc. of Radium emanation, were buried in the growth, were screened by 3/10 mm. platinum, and left in position for twenty-four hours. At the end of six weeks, except for a small nodule, the site of the ulcer was marked only by a healthy scar, but a mass of glands had appeared in the neck. One more tube was buried in the ulcer, and three in the glands of the neck. The remains of the ulcer and the glands of the neck yielded rapidly to the treatment, and the patient has now been quite well for seven months.

Example 2.—Male, aged 47.—The lesion had been in existence for twelve months. At first it looked like a small scratch on the right-hand side of the nose. Subsequently it developed into a nodule, and grew rapidly larger. When first seen it measured 2 x 1 cm., and on it was a

small scabbed area. As the diagnosis was doubtful a piece was removed for section before treatment was given, and, microscopically, it proved to be a squamous celled carcinoma. Two treatments of five hours each were given with Stevenson & Joly's needles, and the small indurated edge which subsequently remained was radiated for twenty-five hours by means of a Radium plate screened by 1.5 mm. of lead. The growth disappeared rapidly, leaving very little deformity of the nose, and the patient has now been well for sixteen months.

CARCINOMA VULVAE.—These cases as a rule have proved very refractory to Radium treatment. Attempts have been made to radiate them by plates, or the implanation of tubes. Little good usually resulted from the treatment. Two cases, however, have been recently treated by means of Stevenson & Joly's needles with considerable benefit. The drawback, however, has been the rather severe and painful reaction. One of the two cases is quoted below.

Example 1.—Female, aged 57.—This patient was suffering for four years from pain on micturition and blood-stained discharge. Shortly before coming to the Radium Institute the pain had much increased and was constant, and the patient's general health was much impaired. When first seen she had a large fungating growth surrounding the posterior and left aspect of the urethra, spreading on to the left labium majus, reaching also to the right labium, and on the left-hand side extending back on the left aspect of the vaginal orifice. There was considerable induration, which was particularly marked just behind the urethra. No enlarged glands were palable in the groins. The growth was treated four times during the course of twelve months by means of needles. On the first occasion two were employed, and at each subsequent application six were used. The time of exposure was twelve hours in each instance. The growth steadily improved from the beginning, the pain and discharge gradually stopped, and when last seen in December, 1916, all that remained was a small button of induration lying behind, and to the left of the urethral orifice. The patient, who had previously been a chronic invalid, was doing her work as usual, and had gained many pounds in weight.

SARCOMA ABDOMINAL MUSCLE.—The three cases hereunder noted are all interesting from the point of view of diagnosis and Radium treatment. The first case is one of true Sarcoma of the left rectus, and other two examples of fibrosis of the abdominal muscles and chronic intestinal myositis respectively. The case of Sarcoma yielded very slowly to Radium treatment, while the other two cleared up extremely rapidly.

Example 1.—Female, aged 29.—In September, 1915, this patient came to the Manchester Royal Infirmary for treatment of a hard growth about 15 cm. long and 7 cm. wide in the upper part of the left rectus abdominis. The Surgeon made an exploratory incision, and a piece of the growth was removed for microscopic examination; it proved to be a myxo-fibro-sarcoma. On one occasion three tubes of Radium emanation, each of a strength of 20 mc. and screened by 1 mm. of silver, were inserted into the growth for twenty-four hours. A considerable reduction in the size of the tumor resulted. It was then decided to continue the treatment entirely by means of heavily-screened Radium plates applied externally for periods of twenty-five hours. The patient has had nine such treatments, and the growth has slowly decreased in size until at present all that can be palpated is a small elongated patch of thickening. The treatment has thus been continued over a period of fourteen months.

Example 2.—Male, aged 42.—This patient was operated on by a surgeon with a view to removing the tumor of the abdominal wall, occupying practically the whole of the abdominal muscle to the right of the middle line, and from the level of the umbilicus downwards. At the time a piece of the growth only was removed for section, but no further operation was performed. The section under the microscope showed extensive fibrosis of muscle, which suggested syphilis, but the Wassermann reaction was negative. Two emanation plates, each containing 28 mc. of Radium emanation and screened by 1.5 mm. of lead, were applied to the growth for twenty-four hours. Two months later no thickening whatever remained, and no recurrence of the growth has taken place, although twenty-one months have elapsed since the treatment was applied.

Example 3.—Male, aged 40.—This patient came to the Royal Infirmary in January, 1915. He had then five weeks' history of swelling of the left thigh and pain down the front of the thigh and leg. A large hard fixed growth could be felt in front of the upper part of the left femur. It was hard, elliptical in shape, and about 15 cm. long. An exploratory incision was made over the tumour, and three emanation tubes containing 80 mc. of emanation were buried in it. A piece was removed for microscopic examination. The section showed the case to be one of chronic interstitial myositis. The growth rapidly became smaller, and the patient has now been free of signs and symptoms for nearly two years.

Uterine Haemorrhage.—Five cases of Uterine Haemorrhage of obscure origin have been treated by Radium during the past two years. Drs. Kelly and Burnam, of Baltimore, have published a paper containing a series of cases of Uterine Haemorrhage, which they have treated by means of Radium with most satisfactory results. They often employed extremely large doses, and frequently a very pronounced general reaction resulted. In these five, however, it has not been customary to use more than 50 mc. of Radium emanation, contained in a silver tube, the wall of which was 1 mm. thick. The tubes were inserted into the cavity of the uterus, and retained there for twenty-four hours, in one case for forty-eight hours. No noticeable reaction followed. One case failed to respond at all to the treatment, and received only one application. The other cases have remained quite well after one dose, with the exception of one which had two.

Exophthalmic Goitre.—A number of cases of Exophthalmic Goitre have improved a great deal from the application of Radium, but

CLASSIFIED RESULTS.

Table II.

Free of disease at the end of the year	105
Improved	317
Not improved	216
Abandoned treatment	91
Died from their disease	90
Too early to note result	34
Prophylaxis	20
Not treated	127
Total	1,000

The number of new cases registered last year was 502

it is felt to be too early to make any extended observations on the results obtained.

RODENT ULCER.—Of the cases reported well last year, two have recurred, but are under control by treatment again. All the other "apparently cured" cases are still well, and there have been some very satisfactory results in several advanced cases. Stevenson & Joly's needles have been very useful in the advanced cases.

TABLE II.

Classification of Cases.

Disease.	Too early to note result	Not Improved	Improved	Free of Disease at end of year	Died from their disease	Abandoned treatment	Total
CARCINOMA:							
Antrum	—	1	—	—	—	—	1
Anus	—	—	1	—	1	—	2
Bladder	—	—	1	3	1	2	7
Breast	9	38	55	8	18	12	140
Cervix of uterus	1	16	37	5	5	8	72
Colon	—	3	1	1	1	—	6
Ear	—	—	—	1	—	—	1
Glands	—	5	2	—	2	1	10
Jaw (upper)	1	—	1	—	—	—	2
Jaw (lower)	1	3	2	—	—	—	6
Larynx	—	1	2	—	1	1	5
Lip	—	—	2	1	—	2	5
Mouth	3	23	28	2	9	4	69
Naso-pharynx	—	—	—	—	2	1	3
Nose	—	—	—	—	1	—	1
Oespohagus	—	1	—	—	5	1	7
Orbit	—	1	—	—	—	—	1
Ovary	—	2	1	1	—	3	7
Pancreas	—	—	—	—	1	—	1
Pharynx and mouth	—	1	—	—	—	—	1
Paget's disease	—	—	1	—	1	—	2
Parotid and sub-maxillary glands	—	4	4	1	1	1	11
Penis	—	1	1	—	—	—	2
Prostate	—	1	1	—	—	—	2
Perineum	—	1	—	—	—	—	1
Pylorus	—	—	—	—	—	1	1
Rectum	1	14	13	—	5	6	39
Scrotum	1	1	—	—	—	—	2
Skin (nose, face, etc.)	—	10	6	13	1	3	33
Spine	—	1	1	—	—	—	2
Stomach	—	1	2	—	1	1	5
Tongue	1	19	2	3	5	4	34
Tonsil	1	6	2	1	—	—	10
Thyroid	—	4	3	1	2	3	13
Urethra	—	—	1	—	—	—	1
Uterus	—	—	1	—	—	1	2
Umbilicus	—	1	—	—	—	—	1
Vulva and vagina	1	3	3	—	2	4	13
Prophylaxis	—	—	—	—	—	—	15
Total	20	162	174	41	65	59	536

CLASSIFIED TABLE OF CASES. TABLE II.—(*continued*).

Disease.	Too early to note result	Not Improved	Improved	Free of Disease at end of year	Died from their disease	Abandoned treatment	Total
SARCOMATA:							
Bladder	—	—	—	—	1	—	1
Buttock	—	—	1	—	—	—	1
Glands	1	1	1	—	2	—	5
Jaw (upper)	—	—	1	—	—	—	2
Jaw (lower)	—	—	1	—	1	—	2
Kidney	—	—	—	—	1	—	1
Long bones	—	3	1	—	—	2	6
Muscle	—	1	4	1	—	1	7
Naso-pharynx	—	—	1	2	2	1	6
Orbit (bony)	—	—	—	—	—	1	1
Orbit	—	1	—	—	—	—	1
Palate	—	—	—	—	1	—	1
Pelvis	—	1	—	—	—	—	1
Periosteum	—	1	1	—	—	—	2
Popliteal space	—	—	1	—	—	—	1
Pleura	—	—	1	—	1	—	2
Parotid gland	—	—	1	—	—	—	1
Retro-peritoneal	—	—	1	—	1	1	3
Ribs	—	—	1	—	—	—	1
Supra-renal gland	—	—	—	—	1	—	1
Tibia	1	—	—	1	—	—	2
Testis	—	—	—	—	—	1	1
Tonsil	—	—	1	—	—	—	1
Prophylaxis	—	—	—	—	—	—	4
Total	2	8	18	4	11	7	54
RODENT ULCER	—	18	30	46	2	5	101
BENIGN TUMORS:							
Certain tumours of doubtful nature	—	1	1	—	—	1	3
Circoid aneurysm	—	—	1	—	—	—	1
Capillary naevus	—	1	4	—	—	1	6
Cavernous naevus	—	—	4	—	—	—	4
Fibroma—Abdominal wall	—	—	1	—	—	—	1
" Hand	—	—	—	—	—	1	1
" Penis	—	—	1	—	—	—	1
" Uterus	—	—	1	—	—	—	1
Glioma orbit	—	—	—	—	1	—	1
Kraurosis	—	1	1	—	—	—	2
Myxoma uterus	—	—	—	—	1	—	1
Myeloid sarcoma	—	2	1	1	—	1	5
Papilloma, bladder	—	1	1	—	—	—	2
" hard palate	—	1	—	—	—	—	1
" skin	—	—	1	1	—	1	3
" vulva	—	—	1	—	—	—	1
Total	—	7	18	2	2	5	34

CLASSIFIED TABLE OF CASES. TABLE II.—(*continued*).

Disease.	Too early to note result	Not Improved	Improved	Free of Disease at end of year	Died from their disease	Abandoned treatment	Total
MALIGNANT TUMORS (various)							
Endothelioma	1	1	4	1	2	—	9
Glands—malignant	—	4	7	—	3	3	17
Lung—malignant	—	—	1	—	—	—	1
Lymphosarcoma	—	3	3	—	3	—	9
Mediastinal tumour	—	—	2	—	2	—	4
Prophylaxis	—	—	—	—	—	—	1
Total	1	8	17	1	10	3	41
GENERAL AND SKIN DISEASES, CHRONIC INFLAMMATION:							
Arthritis deformans	—	1	1	—	—	—	2
Diabetes	—	2	—	—	—	—	2
Excoriation of nipple	—	—	1	—	—	—	1
Exophthalmic goitre	11	3	21	—	—	5	40
Eczema, Chronic	—	—	1	—	—	—	1
Glossitis	—	—	—	—	—	1	1
Granuloma	—	—	—	1	—	—	1
Hodgkin's disease	—	1	8	—	—	2	11
Keloid and vicious cicatrix	—	—	10	3	—	2	15
Lymphatic leukaemia	—	1	1	—	—	—	2
Leucoplakia	—	—	1	—	—	—	1
Lymphangitis (chronic)	—	—	1	—	—	—	1
Lupus vulgaris	—	—	2	—	—	—	2
Lupus erythematosus	—	—	—	—	—	1	1
Mastitis (chronic)	—	1	—	—	—	—	1
Macroglossia	—	1	—	—	—	—	1
Mucous colitis	—	—	1	—	—	—	1
Myositis (chronic)	—	—	—	2	—	—	2
Oto-sclerosis	—	—	1	—	—	—	1
Pruritis	—	1	1	1	—	1	4
Psoriasis	—	—	1	—	—	—	1
Pigmented mole	—	—	2	—	—	—	2
Spring catarrh	—	—	2	—	—	—	2
Spleno medullary leukaemia	—	—	2	—	—	—	2
Sinus (chronic suppurating)	—	—	1	—	—	—	1
Tubercular glands	—	1	2	—	—	—	3
Uterine haemorrhage	—	1	—	4	—	—	5
Total	11	13	60	11	—	12	107

RADIOACTIVITY.*

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Radioactivity is so fundamentally different from all other phenomena in nature that there is nothing with which to compare it. Ordinarily it may be considered as a peculiar property possessed by certain substances which enables them to spontaneously emit radiations which are capable of passing through metals and other opaque bodies. A number of these substances have been discovered and isolated, such as uranium, thorium, radium, polonium and a number of others. These substances are very remarkable, not only on account of the penetrating rays which they emit, but also on account of the enormous amount of energy which they spontaneously give off. One ounce of radium in its complete transformation to the end product will give off enough energy to lift five million tons through a distance of 30 feet. In other words, one ounce of radium will give off enough energy to lift 100 of the largest battleships afloat entirely out of the water. Radio-active substances are remarkable also on account of their scarcity. While uranium and thorium occur in considerable quantities, they are slightly active. Of the various ores in this country which carry radium in commercial quantities, about 350 tons are required to produce one gram, or about 10,000 tons to produce one ounce. Fifty million tons of the same ore would be required to produce one ounce of polonium. These substances are remarkable also because of the frequency and the velocity with which some of them throw off material particles. One gram of radium will throw off about 34 billion alpha particles per second. These are material particles and are thrown of with a velocity of about 10,000 miles per second. These substances are remarkable also because some of them have a life period of only a small fraction of a second, some have a period of a few minutes, some a few hours, some a few days, some a few months, some a few years, some a few thousands of years, and some billions of years. Nothwithstanding these remarkable phenomena, radioactive changes are apparently uninfluenced by external conditions and move along with absolute law and precision.

Radioactivity was discovered in 1896 by an eminent French physicist Henri Becquerel. This was one year after the discovery of X-rays by Roentgen. It had been observed that the cathode rays produce a fluorescence in the X-ray tube at the point where the X-rays are produced. It occurred to Becquerel that possibly substances in nature which are fluorescent might give off radiations similar to X-rays. With a view of testing this theory he made a series of experiments on minerals containing uranium which were known to be fluorescent. In this way he discovered that these substances give off radiations which are capable of passing through what are ordinarily termed opaque bodies. After the discovery of radioactivity, Schmidt and independently Mme. Curie investigated minerals containing thorium and found that these were also radioactive. Then Mme. Curie extended her observations, and examined a large number of minerals containing uranium and thorium. She found that some of the uranium bearing minerals were far more active than uranium itself. This was first thought to be due to the manner in which the uranium was combined chemically. Mme.

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Curie then prepared a large number of compounds in which the uranium was differently combined, and found that the activity was always proportional to the amount of uranium present. These observations indicated that the greater activity of some of the minerals was due to the presence of some substance more active than uranium. Thereupon Mme. Curie, assisted by her husband, began an elaborate series of experiments with a view of isolating this more active material. In 1898 they succeeded in separating two very active substances, one of which they called radium and the other polonium.

Of the various radioactive substances known, radium is by far the most important. Its greater importance, however, is largely due to the fact that it is very active and can be had in quantities sufficient for experimental purposes. Uranium and thorium can be obtained in considerable quantities but they are only slightly active. Certain other substances are very active but it is very difficult to obtain them in quantities sufficient for experimental purposes. The compounds of radium such as the bromide, chloride, sulphate and others are used instead of pure radium for experimental purposes. The activity of these compounds is always proportional to the amount of radium present. Mme. Curie and Dr. Debierne obtained pure radium in a metallic state in 1910. It is a white metal similar to barium. It melts at 700° C., and decomposes water energetically Radium is obtained from pitchblende, carnotite and other uranium bearing minerals.

Three types of rays are given off by radioactive substances, the alpha rays, beta rays and gamma rays. When these rays are subjected to the influence of a strong magnetic field, the beta rays are strongly deflected in one direction, the alpha rays very slightly deflected in the opposite direction, while the gamma rays are not deflected. The gamma rays are about 100 times more penetrating than the beta rays while the latter are about 100 times more penetrating than the alpha rays. The ionizing powers of these rays are roughly represented by the reverse of these ratios.

The alpha rays are positively charged particles thrown off with velocities varying from 9000 to 13,500 miles per second. The alpha particles from any given substance, however, are always thrown off with the same velocity. Each radioactive substance has a characteristic velocity, and hence a characteristic range for the alpha particles which it emits. These particles have been shown to be atoms of helium carrying positive electric charges. This was determined by placing some radium-emanation in a capillary glass tube with walls so thin that the alpha particles would readily pass through. The particles were then collected in an outer tube where the electric charges were neutralized by the surrounding matter, after which the resulting gas was tested spectroscopically and found to be helium.

The counting of the alpha particles has confirmed in a remarkable manner previous estimates of the number of atoms and molecules in a given quantity of matter. This was accomplished in two different ways. Rutherford and Geiger constructed an apparatus which would automatically magnify several thousand times the electrical effect of the alpha particles so that the influence of individual particles could be detected by means of a delicate electrometer. Another method was based on the discovery of Crookes that each alpha particle produces a flash when it strikes a surface of zinc sulphide or certain other substances. By adjusting the apparatus so that only a small fraction of

the total number of particles would strike the substance, the flashes could be counted by means of a microscope. The two methods gave approximately the same result which showed that one gram of radium throws off about 3.4×10^{10} or 34 billion alpha particles per second, and that one gram of radium in equilibrium with its products emits 1.36×10^{11} alpha particles per second.

Various methods have been employed by chemists and physicists to calculate the number of molecules in one cubic centimeter of gas under standard conditions of temperature and pressure. These calculations give a value of about 2.7×10^{19} or 27 billion billion. As already indicated one gram of radium in equilibrum with its products gives off about 1.36×10^{11} alpha particles or atoms of helium per second, or 4.2×10^{18} per year. It has been determined by experiment that one gram of radium in equilibrium produces about 160 cubic millimeters of helium in one year. From this it is evident that 160 cubic millimeters contain 4.2×10^{18} atoms, and that one cubic centimeter contains 2.66×10^{19} atoms or molecules. The helium molecule contains but one atom.

The beta rays consist of negatively charged particles which are identical with the particles of the cathode rays or electrons. These particles are thrown off with enormous velocities, almost equal in some cases to the velocity of light. These rays are far more penetrating than the alpha rays, and are apparently emitted in sets of homogeneous rays. This is indicated by a sort of a band spectrum which they produce on a photographic plate when subjected to the influence of a magnetic field.

The gamma rays are not deflected by a magnetic field. They are a form of radiant energy similar to X-rays. These rays are very penetrating. The rays from radium will pass through the human body or through one foot of iron. The gamma rays are probably produced by the beta rays just as X-rays are produced by the cathode rays. These rays produce secondary beta rays, while alpha rays give rise to low speed electrons called delta rays.

The cause of radioactivity has been very thoroughly investigated, especially by Mme. Curie, Rutherford and Soddy. It has been found that all radioactive substances are chemical elements. So far 34 radio-elements have been discovered. In every case it has been found that radioactivity is a property of the atom. It is due to a disintegration of the atoms. There is, however, no gradual disintegration. Each atom of a radio-element is stable until it undergoes a sort of an explosion and emits an alpha or beta particle, which changes it to a different atom and a different chemical element. For example, an atom of radium throws off an alpha particle with great velocity, which changes the original atom to an atom of radium-emanation, a gas. This substance is also radioactive. Each of its atoms in time emits an alpha particle and themselves become atoms of radium—A, which is a solid. Now we can appreciate to some extent why so much energy is set free in radioactive changes. When steam changes to water heat is set free, and when water changes to ice heat is set free. These are physical or molecular changes. When hydrogen and oxygen combine to form water a much larger amount of heat is set free. This is a chemical change and represents an action between atoms of different kinds. The same is true in the combustion of coal. In the phenomenon of radioactivity there is a disintegration of the atoms themselves with an evolution of energy far greater than that of any known chemical reaction. While

radioactivity is due to a disintegration of the atoms, the cause of the atomic disintegration is not fully understood. Just why certain atoms of uranium, for example, should remain stable for only a brief period, and others remain stable for thousands of years, and still others for billions of years is one of the profound mysteries of this remarkable phenomenon.

Every radioactive substance has its own characteristic radioactive constant, by which is meant the fraction of the whole amount which decomposes in unit of time. The reciprocal of this is the period of average life. The time required for one half of any given amount to disintegrate is called the half period. These periods are constant and are as much of an absolute measure of time as any astronomical event. Radioactive substances disintegrate according to an exponential law. One half of any given amount of radium will disintegrate in about 1700 years, one half of the remainder in 1700 years more, one half of the remainder in 1700 years more, and so on. One half of radium-emanation will disintegrate in 3.85 days, one half of the remainder in 3.85 days more, and so on. Of any given amount of uranium, no matter whether thousands of tons or the thousandth part of one gram, one half will disintegrate in about 5 billions of years, one half of the remainder in 5 billions of years more, and so on.

There are several methods for determining these periods. The first is the direct method applicable to substances with periods varying from a few seconds to several months. For substances like radium-emanation with a half period of 3.85 days, polonium with a half period of 136 days, and a number of others, the rate of disintegration has been determined by direct measurement. Another method is based on the counting of the alpha particles. One gram of radium emits 3.4×10^{10} alpha particles per second. An equal number of radium atoms disintegrate in one second. From this value and the number of atoms in one gram of radium which can be calculated, it is a simple matter to calculate the period of average life and the half period. In this way it has been found that one half would disintegrate in about 1700 years. One gram of uranium emits about 2.37×10^4 alpha particles per second. This would give a half period of about 5 billions of years. The same method gives a half period for thorium of about 13 billions of years. A third method is based on the range of the alpha particle. As already indicated the alpha-particles from any radio-element have a definite velocity and range which is characteristic of that substance. Geiger and Nuttall have found that this range bears a definite relation to the rate of disintegration. This relation was established for substances, the periods of which could be measured directly. When once established it is possible to calculate the period for any substance, for which the range of the alpha particles can be determined. In this way the half periods for radium, uranium and thorium were found to be approximately equal to those already given, while a few substances gave periods of only a small fraction of a second. A fourth method is based on the relative amounts of radioactive substances which exist together in equilibrium. From these ratios and the known periods of certain of the substances it is possible to calculate the periods for the other substances. The values obtained by this method are approximately equal to those obtained by the other methods. The general agreement of the results from the different methods indicates that the values obtained are approximately correct.

The question naturally arises, if these substances are being transformed at such a rate, why many of them were not completely transformed ages ago. From the rate at which radium is disintegrating, any given amount of radium would be practically decomposed in 20,000 years. All the radium which existed 20,000 years ago would be almost entirely disintegrated at the present time. Furthermore, if we assume that the radium which exists in the earth today is but the residuum of a much larger quantity which was originally stored up in the earth, then from the rate at which the radium is and has been decaying, it is a simple matter to calculate that there must have existed, at no very remote period in the past, a quantity of radium greater in bulk than that of the earth itself. This phase of the subject has been very thoroughly investigated, and it has been found that radium and all of its products are continually being formed from a parent substance. As already indicated radium is disintegrating into another radio-element. Radium itself is a disintegration product of still another radio-element called ionium which is likewise a disintegration product. Uranium appears to be the parent radio-element of the whole radium series. This element gives of alpha particles and becomes uranium-X1, this emits beta particles and becomes uranium-X2; this emits beta particles and becomes uranium-2; this emits alpha particles and becomes ionium; this emits alpha particles and becomes radium; this emits alpha particles and becomes radium-emanation; and so on through the A, B, C, D, E and F products. The F product, which is polonium, gives off an alpha particle and becomes the end product which resembles lead. The thorium and actinium series pass through cycles similar to that of the uranium series.

The following examples will show the connection between the disintegration and the regeneration of the radio-elements. Uranium is photographically active due to the emission of beta rays. Crookes observed that if the uranium is dissolved and the solution precipitated with ammonium carbonate and the precipitate dissolved in an excess of ammonium carbonate, a very small residue remains. The solution is no longer photographically active, while the small residue which Crookes called uranium-X is much more active. It was found that the uranium-X lost one half of its beta ray activity in 24.5 days. The solution of uranium regained one half of the original beta ray activity in exactly the same time. In twice this period or 49 days the uranium-X had lost three fourths of its activity, while the solution of uranium in the same time had regained three fourths of the original activity. After the uranium had completely regained its activity and equilibrium had been established, the experiment could be repeated, and this process can be carried on indefinitely during the life of the uranium. If radium-emanation, which is a gas, is completely separated from a given quantity of radium, it will decay to one half of its original volume and one half of its original activity in 3.85 days. The radium from which it was separated will regenerate one half of the original volume of radium-emanation in exactly the same time. In twice this period or 7.7 days, three fourths of the radium emanation will have decayed, while the radium will have regenerated three fourths of the original amount of radium-emanation. When the radium has regenerated the original amount of radium-emanation and equilibrium has been established, the process can be repeated. Other examples could be given but these are sufficient to show that the radio-elements are not only being regenerated, but that the same law which controls their regeneration controls also

their disintegration. In other words, the radioactive constant of a radio-element measures its rate of formation as well as its rate of decay.

The radio-elements, except for their high atomic weights and their properties of radioactivity, have no special chemical characteristics to differentiate them from other elements. Under the influence of radio-active rays water is decomposed forming hydrogen, oxygen and hydrogen peroxide; carbon dioxide is decomposed into carbon, oxygen and carbon monoxide; oxygen is converted into ozone; iodine is liberated from solutions of iodoform; ammonia is changed to hydrogen and nitrogen, while hydrogen and nitrogen unite to form ammonia. Many substances become fluorescent under the action of these rays, while others completely change their colors. The fact that these rays are such active agents in producing chemical and physical change is in itself of great interest, but it is not due to this fact, however, that radio-active substances and their radiations occupy such a prominent place in chemistry and physics. Radioactivity has made it possible to actually experiment with individual atoms. It has given us direct evidence of the existence of atoms. It has greatly extended our knowledge of the nature of atoms, and it has given us definite evidence of the change of one chemical element into another. When a radio-element ejects an atom of helium, it not only changes the weight of the original atom by an amount equal to the weight of the helium atom, but it removes two units of positive charge from the nucleus of the atom. The emission of a beta particle produces no appreciable change in the atomic weight, but adds one unit of positive charge to the nucleus. In this way elements of different atomic weights and different valencies are produced. It happens in some cases that several radio-elements having different atomic weights occupy the same place in the periodic system. These elements appear to be chemically identical and nonseparable. Soddy has suggested the term "isotopes" for such elements. The magnitude of the nuclear charge of the atom, rather than the atomic weight, seems to be the controlling factor in the periodic arrangements of the elements.

The biologist has found that radioactive rays have a very pronounced effect on living tissue. The vital functions of the living cell are materially modified by the action of these rays. This fact was first observed by the earlier experimenters in radioactivity who found that radium, when left too long in contact with or near the body, would produce severe burns. This naturally led to experiments with radium in the treatment of pathologic tissues. Today radium occupies a prominent place in therapeutics in the treatment of skin disease, malignant and nonmalignant growths, and various other diseases. Radium-emanation has been given internally in various ways for various diseases with successful results. Radium in equilibrium with its products gives off the three types of radiation. Very penetrating gamma rays are emitted by the radium-C. In as much as radio-active rays effect all normal tissues, and as these tissues differ greatly in their powers of resistance, great care is necessary in administering radium treatments. Owing to the scarcity of material and possibly for other reasons, radium therapy has not received the attention it deserves. One difficulty arises from the fact that very few physicians and surgeons are familiar with the chemistry and physics of radioactive substances, and on the other hand chemists and physicists, in most cases, know very little about therapeutics. In order to administer so potent an agent with

the proper technique, with safety and with the most beneficial results, it may be necessary, for some time at least, for the physician and surgeon to work in conjunction with a chemist or physicist who is familiar with these substances. Radium institutes have been established at various places throughout the world where a large number of patients are being treated. Owing to the scarcity and high cost of radium, the radium institute seems to be the best method whereby the general public can receive the benefit of these treatments. In as much as radium is now being produced on a comparatively large scale in this country, it is to be hoped that radium therapy may receive more attention, and that its place in the treatment of disease may be more definitely established.

It is only natural that so remarkable a phenomenon as radioactivity should exert an important influence on almost every branch of natural and physical science. Reference has already been made to its influence in chemistry, physics, biology and therapeutics. Of great interest also is its possible influence in geology and cosmogony. Having once established the fact that radioactive substances spontaneously give off an enormous amount of energy, and that this process may continue in some cases for billions of years, it remains to be considered what influence this may possibly have on the supply of heat which is continually being radiated by the earth, and the far greater amounts which are being radiated by the sun and stars. It has been suggested by some that any attempt to connect radioactivity as an important factor in geologic and cosmic phenomena is highly speculative. It should be remembered, however, that all theories relative to the origin of the earth and celestial bodies, and all theories relative to the sources of the heat which is being radiated by these bodies is more or less speculative. The assumption that radioactive or atomic transformation may be an important factor in supplying the heat which is thus being radiated is probably no more speculative than any other theory. In considering this problem Soddy says, "primary sources of natural energy, by virtue of which the universe keeps going over immense periods of time, are to be sought, not in the great masses of glowing matter dotted about the heavens, nor in their motions under gravity, nor in any of the grosser relations between matter and energy in bulk, but in the individual atoms out of which it is made up."

The age of the earth as estimated by Lord Kelvin is entirely inadequate from the standpoint of the geologist. The oldest forms of organisms found in fossil remains, and the still older forms of life of which no traces have ever been found must have lived under temperature conditions somewhat similar to those which exist today. The enormous lapse of time since the first appearance of life on the earth, possibly no less than a thousand million years, is greatly in excess of the time which has been estimated for the age of the earth. Efforts have been made to estimate the ages of different minerals and rocks found in the crust of the earth from the relative amounts of radioactive substances and helium gas which they contain. Knowing the rate at which these substances are producing helium, it is a simple matter to calculate the time required for its formation. Strutt, Joly and others have investigated this subject very thoroughly. The results vary from about 8 millions of years for the more recent formations to 740 millions of years for some of the oldest forms of rocks. No doubt some of the helium escapes, so that these values are in reality too low. As already suggested lead appears to be the end product of the uranium series.

Boltwood and others have endeavored to estimate the ages of different minerals and rocks from the relative amounts of lead and uranium present. These results are somewhat higher than those obtained from the helium content. This method gives about 340 millions of years for the Carboniferous rocks, 430 millions of years for the Silurian, and from 1000 to 1640 millions of years for the Pre-Cambrian. In these estimates it is assumed that all of the lead is of radioactive origin. These results are more in accord with the demands of the geologist. It remains to be considered, however, how the temperature of the earth has been maintained for so long a period.

Reference has already been made relative to the scarcity of radioactive substances. Notwithstanding their scarcity, they occur almost everywhere. They are found in practically all rocks whether igneous or sedimentary. They occur likewise in soils and practically all springs. The radium content of the oceans is probably measured in thousands of tons, while the beds of the oceans contain a much larger quantity. Radium-emanation occurs everywhere in the atmosphere. On an average there is about as much thorium as uranium in rocks, but there is no definite relation between the amounts in any type of rock. The heating effect of these substances, of course, depends on the amount present. Rutherford has estimated that one part of radium in twenty million million parts of the earth's crust would supply all the heat which is now being radiated by the earth. Strutt, Joly and others have examined a large number of rocks at different depths in the earth's crust, and have found that there is present considerably more radioactive substances than would be required to maintain the present temperature of the earth. Strutt has suggesed that the radioactive materials probably exist only in the crust of the earth and do not extend into the core. Joly, on the other hand, assumes that these substances probably exist in the core as well as the crust of the earth. If this theory is true, it is impossible, with our present knowledge, to foretell the ultimate result of the presence of such quantities of radioactive substances in the core of the earth. The heat produced by these substances may be dissipated by slow conduction, by means of volcanoes and otherwise. Unless this happens the temperature of the core of the earth will increase a few thousand degrees every hundred millions of years. If the radio-elements continue to disintegrate at the increased temperature and under the enormous pressures to which they are subjected, then the time must come when the earth's crust will yield to the gradually increasing pressure from within. Joly suggests that there is no evidence to indicate that the earth has not been incandescent more than once, nor assurance that it will not become incandescent again. If the helium which occurs in the atmosphere is entirely of radioactive origin, Joly says that it could not have been produced in geologic times, and intimates that this may be an evidence of pre-geologic time. "Our geological age," he says, "may have been preceded by other ages, every trace of which has perished in the regeneration which has heralded our own."

The influence of radioactive substances in cosmic phenomena is more difficult to determine. In the first place it is very difficult to detect these substances in any celestial body. Some observers claim to have detected radium and uranium in the sun and certain stars by means of the spectroscope. Whether these tests have furnished conclusive evidence or not, there are very good reasons for assuming the presence of radioactive substances in these bodies. The

high atomic weights of the radio-elements would have a tendency to keep them near the photosphere, and thus make their spectroscopic detection very difficult. The apparent uniformity of matter throughout the universe, the probable common origin of the earth and the sun, the presence of radioactive substances in certain meteorites, the tendency of radiation pressure to distribute matter throughout the universe, and the presence of helium in the sun and the stars are evidences of the presence of radioactive substances in celestial bodies. Apparently the only argument against the presence of these substances in the sun and stars is that these bodies may not yet have cooled down to a temperature at which elements of such high atomic weights can be formed. This may be true of the hottest stars. The presence of helium in such stars may be an evidence of the simple structure of the helium atom rather than an evidence of the presence of radioactive substances. It is impossible to say at what temperature the evolution of the radio-elements is complete and devolution begins. If we assume the uniformity of matter throughout the universe, however, the time must come in the life of every sun and star when they will contain radioactive substances.

The influence of radioactivity in maintaining the sun's heat can only be conjectured. Lord Kelvin has estimated that the sun has probably not illuminated the earth for more than 100 millions of years, and intimated that it could not continue to furnish the heat and light essential to life for many millions of years more, unless other and unknown sources of energy are available. Radioactivity is a possible source of energy which may help to maintain the sun's heat. It is impossible to determine how much energy is supplied in this way. If radioactivity is limited to the uranium, thorium and actinium series as it appears to be on the earth, then it is probably not a very important factor in supplying the enormous amount of heat which is now being radiated by the sun. Rutherford has calculated that if the sun consisted entirely of uranium in equilibrium with its decomposition products, the heat generated by the active matter would be only about one fourth of that which is now being radiated. It may be, however, that some of the so called stable elements are radioactive under the conditions which exist in the sun. It would require only about two and one half parts of radium or any substance equally active in one million parts of the sun to supply all the heat which is now being radiated by the sun. As already indicated, however, it is impossible with our present knowledge to determine the quantity of radioactive material in any celestial body. If there is present any considerable quantity of radioactive substances in any sun or star it will not cool as an ordinary body, and its life may be measured in billions of years. It is possible that celestial bodies contain sufficient quantities of radioactive substances to ultimately heat them to incandescence after the surface has once become cooled, and this may continue to happen until the radioactive material is too far exhausted to again repeat the process. This possibilty has been admirably suggested by Joly. He says: "When a new star appears in the heavens, may this not be a manifestation of the infinitely little over the infinitely great—the unending flow of energy from the unstable atoms wrecking the stability of a world."

Radioactivity has revealed the fact that the atom is a great storehouse of energy. This is true of all atoms, as there is probably no more energy associated with the radio-elements than with other elements in proportion to their atomic weights. What influence these discoveries

may exert upon the human race remains for the future to determine. Realizing that human life is so intimately dependent upon an adequate supply of energy, it is interesting to contemplate the result of being able to control and utilize the potential energy of the atom. It would probably cause more radical changes in our customs and habits than any combination of social and political influences could produce. It would make us independent of heat and cold, of drouth and flood; and it would enable us to "transform a desert continent and thaw the frozen poles." When we consider the new and unexplored world which radioactivity has revealed, the intimate knowledge it has given us of the constitution of matter, the possible influence of radioactive substances in geologic and cosmic phenomena, the possibilities which the vast stores of energy have suggested and the influence of radioactive rays on the vital functions of the living cell, it is impossible to say what part radioactivity may have played and is playing in the economy of nature; and it is impossible to even predict what influence it may have in the economy of life itself. It may be, as Professor Soddy has suggested, that radioactivity including atomic transformation is competent to be the mainspring of the universe.

REVIEWS AND ABSTRACTS.

George E. Pfahler, M. D. (Philadelphia.) The Treatment of Malignant Disease About the Mouth by Combined Methods. Journ. A. M. A., Vol. LXVII, No. 21, pp. 1502-1505, November 18, 1916. "It will undoubtedly be many years before the medical profession and the laity will realize fully the importance of prophylactic measures. We shall have to contend, therefore with malignant disease in all stages, and I have come to believe that no single method is sufficient for the treatment of this malignant disease. We have at our command at least four different methods for the treatment of malignant disease, especially as applied to the mouth. These are surgical removal, local destruction by means of electrothermic coagulation, deep roentgenotherapy, and the application of radium in the mouth."

"Every case of epithelioma about the mouth should have the disease destroyed locally by electrothermic coagulation, or thoroughly excised surgically. I have come to believe that the local destruction in the mouth or about the lips by means of electrothermic coagulation will give better results than excision, and generally with less loss of tissue; but I also would urge when palpable metastatic glands are present in the neck, that they be excised surgically even though the disease inside the mouth or on the lips is destroyed by electrothermic coagulation. Following this destruction or removal, deep roentgenotherapy should be thoroughly applied over the wound, and over the glandular area, making use of as much crossfiring as is possible. I am sure that this will give an improvement in the results over those cases in which surgery alone is depended on."

"*Surgery.*—The surgical removal of malignant disease about the mouth has been so thoroughly reviewed recently by Blair and by Bloodgood that I need only refer to their writings. Their results show that when surgery alone is depended on, thorough local excision and complete dissection of the glands draining the diseased area give the best results."

"Advantages of Electrothermic Coagulation: 1. The disease is destroyed by conductive heat which gives a zone of devitalization without actual destruction of healthy tissue, thereby saving local tissue when necessary. 2. There are no raw tissues to permit the transplantation of malignant cells. 3. There are no blood or lymphatic vessels opened up through which the disease can be disseminated during the operation. 4. One does not have hemorrhage to contend with, though, in tongue cases, there is some danger of a secondary hemorrhage. 5. There are no open wounds and no danger of local infection."

"Disadvantages of Electrothermic Coagulation: 1. There is complete destruction of all the tissue between the two electrodes. Therefore, there is no chance of saving the blood vessels or nerves which are in close proximity to the disease. 2. There is necessarily considerable sloughing and foul odor associated during the first two or three weeks, but there is no danger of infection, and I have never had infection of the tissues develop in any case of electrothermic coagulation in any part of the body. There is considerable reaction dur.ng the first few days after the operation. 3. It leaves an open area which is healed by granulation, but at times this healing must be followed by much disadvantage because so much less in quantity, and so less definitely. It is truly remarkable how a very ugly wound in the early stages will close in and develop rounded edges so as to become very insignificant. I have in mind the lip, cheek and tongue cases."

"Deep Roentgenotherapy.—Object: The object of the roentgenotherapy is to control or destroy the outlying cells or metastases that may be missed in the coagulation process. Therefore, the treatment must be thorough and given with the understanding that disease may still be present; for if one is sure of having destroyed all of the malignant disease, there is no object in adding the roentgenotherapy. This treatment must always be given with the technic used for deep disease, for one should never leave any superficial or visible disease behind."

"Radium.—I believe that the place of radium in the treatment of malignant disease about the mouth is within the mouth and not on the outside. I can see no advantage of radium over Roentgen rays, and much disadvantage because so much in quantity, and so less definitely controlled when applied externally. The Roentgen rays can be applied externally with more power and their direction and distribution perfectly controlled, while the quantity used is immensely greater than that obtained from an quantity of radium of which I know today. When the radium is applied inside the mouth, however, all these arguments disappear, for one is able to bring the radium in close contact ofttimes with the disease, and when filtered through at least 0.5 mm. of silver, and when one applies approximately 600 milligram hours of radium, a very decided, and I believe, beneficial effect can be added. I believe, however, that even when the radium is used within the mouth, there should be nothing lost, and much gained by adding the deep roentgenotherapy from as many angles as possible, applied externally. The advantage of radium is that we are adding this inside treatment. In other words, we are applying another crossfiring effect by means of radium. It is this combination which I use, and I believe the most practical."

Classification and case reports are given.

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